File Specification for GEOS-5 DAS Gridded Output

Addendum for Supporting the *Tropical Composition Cloud and Climate Coupling (TC4)* Mission

Global Modeling and Assimilation Office
Goddard Space Flight Center, Greenbelt, Maryland

http://gmao.gsfc.nasa.gov

Release Date: 14 May 2007

Based on the GEOS-5 File Specification Version 6.1
To support NASA instrument teams with GEOS-5 DAS V1.0

This addendum maintained by Arlindo da Silva (Arlindo.dasilva@nasa.gov)
Permission to quote from this document should be obtained from the GMAO.

Michele Rienecker
Global Modeling and Assimilation Office
Earth Sciences Division
NASA Goddard Space Flight Center
Greenbelt, Maryland 20771

REVISION HISTORY

Version Number	Revision Date	Extent of Changes	Approval Authority
6.1-TC4-r3	05/14/2007	Merged with TC4 GEOS-5 Data document.	

Table of Contents

1. Introduction

The "*File Specification for GEOS-5 DAS Gridded Output"* document[1] describes the gridded output files from the version 5 of the Goddard Earth Observing System Data Assimilation System (GEOS-5 DAS), which supports level-4 product generation. This document describes additional data products being generated in support of the Tropical Composition Cloud and Climate Coupling (TC4) Mission[2].

The GMAO operational assimilation runs 4 times/day approximately 12 hours behind real-time. During the TC4 Flight Campaign (16 July through 8 August 2007) the GMAO will produce twice daily ½ x 2/3 degree forecasts at 00Z and 12Z and once daily ¼ x 1/3 degree forecasts at 12Z with data products tailored to the needs of the TC4 Mission. Information on the status of GMAO product generation can be found at http://gmao.gsfc.nasa.gov/operations/.

2. Format and File Organization

GEOS-5 DAS files are in HDF-EOS format, which is an extension of the Hierarchical Data Format (HDF), Version 4 developed at the National Center for Supercomputing Applications (NCSA); files from GEOS-5 forecasts will be in a CF-compliant HDF-4 format without the HDF-EOS extensions. Each GEOS-5 file will contain a single HDF-EOS grid, which in turn contains a number of geophysical quantities that we will refer to as "fields" or "variables." Some files will contain 2-D variables on a lon/lat grid and some files will contain 3-D variables on the same lon/lat grid but with an additional vertical dimension. In order to keep individual file sizes manageable, all files will contain only one valid data time, in contrast to the daily files produced by earlier GEOS systems.

In addition to the geophysical variables, the files will have SDS arrays that define dimension scales (or coordinate variables). There will be two distinct scales for each dimension, which will insure that a wide variety of graphical display tools can interpret the dimension scales. In particular, there is a set of dimension scales that adhere to the CF conventions as well as the older COARDS conventions (see References).

Due to the large size of these data files we will use the internal GZIP compression capability of HDF-4, which provides a lossless compression of scientific data. In order to achieve a higher level of compression, we will pre-condition the data values to be archived by "shaving" digits off the mantissa of each 32 bit float point prior to applying the GZIP lossless compression. Using this lossy compression scheme, we can reduce file sizes by 50% to 80% or even more, and yet not require any adjustment in the end user's software. Unlike SZIP compression in HDF-4, GZIP compression comes standard with HDF-4 and these files can be directly read by desktop applications such as IDL, Matlab and GrADS.

3. Assimilated Instantaneous Products vs. Model-generated Time-averaged Products

GEOS-5 gridded output files are identified as either instantaneous or time-averaged products. For upper-air fields, all pressure products are instantaneous and all lagrangian control volume (lcv) products are time-averaged. Single-level or surface products may be either instantaneous or time-averaged. The GMAO is no longer producing time-averaged pressure products, as was done with

[1] Available from http://gmao.gsfc.nasa.gov/operations/GEOS5_File_Specification.pdf .
[2] TC4 Home Page: http://cloud1.arc.nasa.gov/tc4/

GEOS-3 and GEOS-4.

The instantaneous products are generated by the analysis segment of the assimilation process. All instantaneous products contain fields that are snapshots of a specific time, with a single time per file. Upper-air products such as "inst3d_met_p" have a time frequency of 6 hours, with data valid at the four standard *synoptic times* (00 GMT, 06 GMT, 12 GMT, and 18 GMT). Instantaneous single-level products, such as "inst2d_met_x," have a time-frequency of 3 hours, valid at the times listed above, plus the interim times of 03 GMT, 09 GMT, 15 GMT, and 21 GMT.

The time-averaged products are generated by the Incremental Analysis Update (IAU) segment of the analysis process. The IAU gradually forces the model integration through the 6-hour period between analysis times. Time-averaged products are averaged over a 3-hour period for single-level files and over a 6-hour period for lcv files. Single-level products consist of 8 files per day, with time-stamps at the center of the 3-hour averaging interval (i.e., 01:30, 04:30, 07:30, 10:30, 13:30, 16:30, 19:30, and 22:30 GMT), and there is a single time period per file (e.g., the first file for a given day is time stamped with 01:30 GMT and represents the average between 00 GMT and 03 GMT). Time-averaged lcv-level products consist of 4 files/day, with time-stamps of 00, 06, 12, and 18 GMT, with each file time-stamped at the center of a 6-hour average (e.g., the first file of a given day is time-stamped with 00 GMT and represents an average between 21 GMT of the previous day and 03 GMT of the given day).

4. Grid Structure

4.1 Horizontal Grids

GEOS-5 gridded output will be provided on 2 different horizontal grids:

a) ***Global 2/3 x 1/2 degree longitude-latitude horizontal grid***, consisting of IM**=540** points in the longitudinal direction and **JM=361** points in the latitudinal direction. The horizontal grid origin is the lower-left corner of the first grid box (I=1, J=1) and represents the geographical location (180W, 90S). Latitude and longitude as a function of their indices (I,J) can be determined by:

i. $LON_I = -180 + (I-1) * dLON, \quad I=1, IM$
ii. $LAT_J = -90 + (J-1) * dLAT, \quad J=1, JM$

where dLON = 2/3° and dLAT = 1/2°. For all parameters of each file, a grid point represents the center of a box, i.e., the value at (LON=0, LAT=0) represents a box bounded by the points (LON=-0.33, LAT=0.25), (LON=-0.33, LAT=-0.25), (LON=0.33, LAT=-0.25), and (LON=0.33, LAT=0.25). Scalar values usually represent the volume mean within the box.

b) ***Global 1/3 x 1/4 degree longitude-latitude horizontal grid***, consisting of IM**=1080** points in the longitudinal direction and **JM=721** points in the latitudinal direction. The horizontal grid origin is the lower-left corner of the first grid box (I=1, J=1) and represents the geographical location (180W, 90S). Latitude and longitude as a function of their indices (I,J) can be determined by:

iii. $LON_I = -180 + (I-1) * dLON, \quad I=1, IM$
iv. $LAT_J = -90 + (J-1) * dLAT, \quad J=1, JM$

where dLON = 1/3° and dLAT = 1/4°. For all parameters of each file, a grid point represents the center of a box, i.e., the value at (LON=0, LAT=0) represents a box bounded by the points (LON=-0.33, LAT=0.125), (LON=-0.33, LAT=-0.125), (LON=0.1666, LAT=-0.25), and (LON=0.1666, LAT=0.25). Scalar values usually represent the volume mean within the box.

4.2 Vertical Grid

The **vertical structure of gridded products** will have three different configurations: single-level (can be vertical averages or surface values), pressure-level, or lcv-level. Single-level data for a given variable appear as 3-dimensional fields (x, y, time) with multiple times spanning multiple files, while pressure-level data appear as 4-dimensional fields (x, y, z, time). Pressure-level data will be output on **LMP=26** pressure levels (hPa): 1000, 975, 950, 925, 900, 850, 800, 750, 700, 650, 600, 550, 500, 450, 400, 350, 300, 250, 200,150, 100, 70, 50, 30, 20, 10. The appropriate grid structure will be specified both in the filename and the metadata.

The GEOS-5 terrain-following lagrangian control volume (lcv) coordinates are similar to an eta coordinate system. There are **LM=72** layers in the 5 lcv products: tavg3d_dyn_v, tavg3d_cld_v, tavg3d_mst_v, tavg3d_tmp_v, and tavg3d_wnd_v, with the values representing a layer-mean unless otherwise noted. Additionally there is the tavg3d_prs_v product, which contains the **LM**-layer 3D variable $\mathbf{PL}_{\mathbf{ijl}}$, which defines the layer-mean pressure at every horizontal grid-point. Note that the delta pressure for each layer ($\mathbf{DELP}_{\mathbf{ijl}}$) and the surface pressure ($\mathbf{PS}_{\mathbf{ij}}$) are also included in the tavg3d_prs_v product, allowing one to easily compute the pressure at the edges of each layer. In the GEOS-4 eta files, one could compute the pressure on the edges by using the "ak" and "bk" values and the surface pressure; once the edge pressures were known, they could be used to compute the average pressure in the layer. In GEOS-5, the full 3-dimensional pressure variables are explicitly provided at both layer centers ($\mathbf{PL}_{\mathbf{ijl}}$) and layer edges ($\mathbf{PLE}_{\mathbf{ijl}}$). As of this writing the pressures reported are on a hybrid-sigma coordinate, and could be obtained from the "ak-bk" relationship. But this may change in the future and so users should rely on the reported 3-dimensional pressures and not attempt to compute them from "ak" and "bk". Figure 1 is a schematic (not to scale) of the GEOS-5 LCV coordinate system. Note that the indexing in the vertical starts at the top, i.e., lcv layer 1 is the layer at the top of the atmosphere while lcv layer **LM** is adjacent to the earth's surface.

Variables that are only defined on layer edges (such as vertical fluxes between layers) are provided in the tavg3d_met_e product, which has **LM**+1 levels representing the top and bottom edges of the **LM** lcv layers of the model. This product also contains the 3-D variable edge pressures, **PLE**.

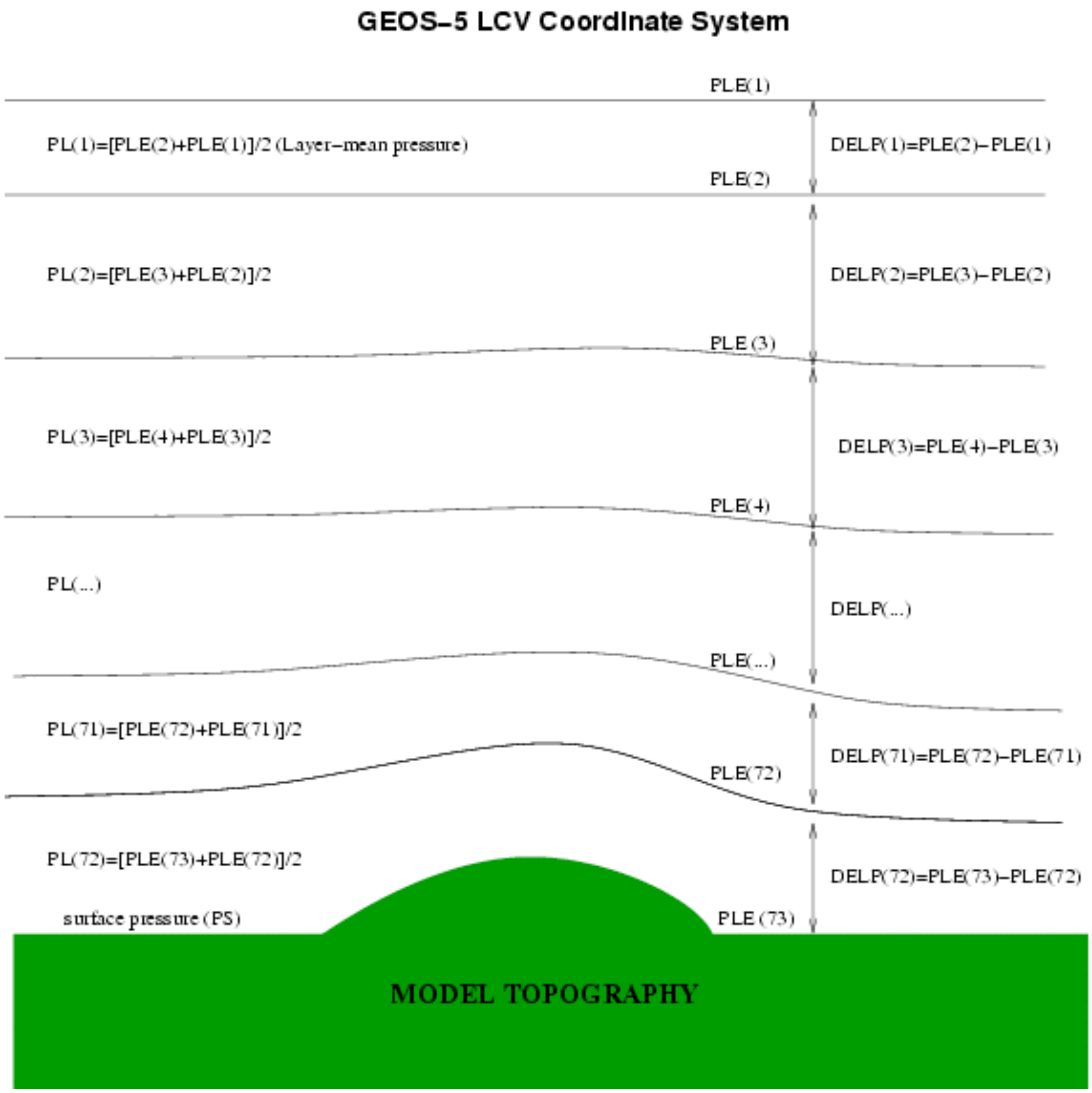

Figure 1: Schematic of GEOS-5 LCV coordinate system

5. File Naming Convention

The standard generic complete name for the *assimilated* GEOS-5 configuration products will appear as follows:

expid.filetype.yyyymmdd_hh$nn.hdf

GEOS-5 *forecasts* files have an additional date string (separated by "+") to indicate the initial conditions for that forecast.

expid.filetype.YYYMMDD_HH+yyyymmdd_$hhnn.hdf

A brief description of the node fields appear below:

expid:
Experiment Identification. The GEOS-5 DAS data sets will be labeled:

GEOS5##

where ## is a two-digit number. The first operational release of GEOS-5 will have an experiment identification of GEOS501. When a modified version of GEOS-5 is used for either forward processing or reprocessing, we will increment the ## appropriately. As updated versions of the GEOS software are implemented in operations, the cvs tag in the metadata parameter "History" will be modified. Information on version upgrades will also be available on the GMAO operations status web page (http://gmao.gsfc.nasa.gov/operations/).

filetype:
The major file types are subdivided into file collections. Collections contain several fields with common characteristics. These collections are necessary to keep file sizes reasonable. Each file type will contain the following information:

type/dimension_group_level

type/dimension:

There are four possible type/dimension conventions for the DAS data products:

inst2d - 2-dimensional instantaneous fields (no time averaging).
inst3d - 3-dimensional instantaneous fields (no time averaging).
tavg2d - 2-dimensional 3-hour time-averaged fields, time-stamped at the center of the averaging period. For example, 04:30 GMT30z output would be a 3 GMT – 6 GMT time average).
tavg3d - 3-dimensional 6-hour time-averaged fields, time-stamped at the center of the averaging period. For example, 6 GMT output would be a 3 GMT – 9 GMT time average.

group:

met: meteorological fields
prs: pressure fields
dyn: dynamical fields
mst: moisture fields
tmp: temperature fields
wnd: wind fields
chm: CO, CO2 and O3
aer: aerosols: dust, sea salt, sulfates and carbonaceous aerosols

level: There are four possible level types for the DAS data:

x: single-level data (surface, column-integrated, single-level)
p: pressure-level data (see Appendix C for pressure levels)
v: lagrangian control volume (lcv) layers
e: lagrangian control volume (lcv) layer edges

yyyymmdd_hhnn:
This node defines the date and time of the data in the file.

yyyy - **y**ear string (e.g. "2002")
mm - **m**onth string (e.g. "09" for September)
dd - **d**ay of the month string (e.g. "10" for the tenth day of the month)
hh – valid **h**our
nn – valid mi**n**utes (either "00" or "30"); the **nn** digits may ob omitted if all files have **nn** = 00.

YYYMMDD_HH
Similarly, this denotes the date and time of the initial conditions for the forecasts.

EXAMPLE:

GEOS501.tavg3d_dyn_v.20020915_00z.hdf

This is an example of a DAS filename from the operational GEOS-5 DAS. The data are 6-hour time averaged output on lcv levels (rank 3:). The filetype consists of dynamical fields. The valid time for the data is Sep 15 at 00 GMT, which represents the 6-hour average from Sep 14 at 21 GMT through Sep 15 at 03 GMT. See the discussion on time-averaged data in section 3 for more information.

6. TC4 File Collections

6.1 Summary of Data Products

Table 1 summarizes the forecast files to be produced during TC4. The meteorological products **inst3d_met_p** and **tavg2d_met_x** will be produced at ½ x 2/3 degree resolution twice daily (00Z and 12Z) and ¼ x 1/3 degree horizontal resolution once a day (12Z). The remaining aerosol and chemical constituent files will produced only at ½ x 2/3 degree resolution twice daily. See sections 6.3 and 6.4 for a detailed list of variable names.

The analysis data products will consist of the standard GEOS-5 DAS near real-time offerings, supplemented by the aerosol and chemical constituent products listed in Table 2. All these products will be produced in ½ x 2/3 degree resolution only. See the "*File Specification for GEOS-5 DAS Gridded Output"* document for a list of standard products, and sections 6.5 for a detailed list of variable names in the supplemental files.

Table 1. Summary of GEOS-5 Forecast files

File Type	Description	Variables	Res .(*)	Ref. Times	File Freq	GZIP size Mb/fcst
Inst3d_met_p	Instantaneous 3D meteorological state on pressure coordinates	**U, V,T, Q, OMEGA, H, RH, EPV,** *PS, SLP*, PHIS, *TSKIN, ___10M*	D26 E26	0Z, 12Z 12Z	3 hr	3360 6592
Tavg2d_met_x	Time averaged 2D misc fields, single-level/vertical average	*PS,* PHIS, *SLP, PREC___, CLD___, TROP___, PBLH, CAPE, TSKIN, TQV, TQL, TQI*	D E	0Z, 12Z 12Z	3 hr	340 504
Tavg3d_chm_p	Time averaged 3D chemical state on pressure coordinates	*LWI, PS*, **CO, CO2, O3**	D26	0Z, 12Z 12Z	3 hr	1240
Tavg2d_chm_x	Time averaged 2D chemical state, single level/vertical average	*SCO, TCO, SCO2, TCO2, SO3, TO3*	D	0Z, 12Z 12Z	3 hr	100
Tavg3d_aer_p	Time averaged 3D aerosol concentration on pressure coordinates	*LWI, PS*, **DU, SS, SO4, SO2, BC, OC**	D26	0Z, 12Z	3 hr	2440
Tavg2d_aer_x	Time average 2D aerosol	Many (103): AOT,	D	0Z, 12Z	3 hr	1640

	diagnostics	surface/column mass, production & loss terms				
Inst2d_hwl_x	Instantaneous 2D fields for Hyperwall	*SLP, H500, DUAOT, SSAOT, BCAOT,OCAOT, SO4AOT, TCO, TCO2, TO3*	D	0Z, 12Z	1 hr	660

(*) "D" resolution corresponds to 2/3° longitude x 1/2 ° latitude, while "E" resolution corresponds to 1/3 ° longitude x 1/4 ° latitude. The 2 digits specify the number of vertical levels.

Table 2. Summary of GEOS-5 Analysis/Assimilation files: additions to GEOS-5 File Specification.

File Type	Description	Variables	Res.	File Freq	GZIP Size Mb/day
Inst3d_chm_v	Instantaneous 3D chemical state on LCV coordinates	*LWI, PS*, **DELP, CO, CO2, O3**	D72	6hr	904
Tavg3d_chm_p	Time averaged 3D chemical state on pressure coordinates	*LWI, PS*, **CO, CO2, O3**	D26	3 hr	248
Tavg2d_chm_x	Time averaged 2D chemical state, single level/vertical average	*SCO, TCO, SCO2, TCO2, SO3, TO3*	D	3 hr	20
Inst3d_aer_v	Instantaneous 3D aerosol state on LCV coordinates	*LWI, PS*, **DELP, RH, DU(5), SS(5), SO(4), BC(2), OC(2)**	D72	6hr	4264
Tavg3d_aer_p	Time averaged 3D aerosol concentration on pressure coordinates	*LWI, PS*, **DU, SS, SO4, SO2, BC, OC**	D26	3 hr	976
Tavg2d_aer_x	Time average 2D aerosol diagnostics	Many (102): AOT, surface/column mass, production & loss terms	D	3 hr	328
Inst2d_hwl_x	Instantaneous 2D fields for Hyperwall	*SLP, H500, DUAOT, SSAOT, BCAOT, OCAOT, SO4AOT, TCO, TCO2, TO3*	D	1 hr	44

6.2 Calculation of file sizes

Below are the variables that are output into each **inst** file. These are instantaneous fields (no time averaging). The approximate size of each file below is determined by the following:

A x B x C x D x E = bytes/file

where:

A: X-Dimension
B: Y-Dimension
C: Vertical dimension
D: Number of fields in file
E: Number of bytes per floating point number

The method for calculating sizes is the same in 6.1 and 6.2.

NOTE: All HDF variable names are UPPERCASE. Italicized sizes in ( ) are estimates of the compressed file size, which will vary from day to day.

6.3 Forecast Files – ½ by 2/3 Degree Resolution: Twice-daily at 00Z and 12Z

- **inst3d_met_p** (1 time per file, 8 files per day: 00, 03, 06, 09, 12, 15, 18, 21 GMT)
  Description: 3D meteorological state, instantaneous on pressure coordinates
  Dimensions:
  longitude: 540
  latitude: 361
  vertical pressure levels: 26
  Number of 3D variables: 8
  Number of 2D variables: 10
  Size: 168 MB (84 MB)
  Size/day: 1344 MB (672 MB)

Variable Name	Description	Units
H	Geopotential height	m
EPV	Ertel Potential vorticity	$m^2kg^{-1}s^{-1}$
OMEGA	Vertical velocity	Pa s^{-1}
QV	Specific humidity	kg kg^{-1}
RH	Relative humidity	percent
T	Air temperature	K
U	Eastward wind component	m s^{-1}
V	Northward wind component	m s^{-1}
PS	Surface pressure	Pa
SLP	Sea-level pressure	Pa
PHIS	Surface geopotential	m^2s^{-2}
TSKIN	Skin temperature	K

Variable Name	Description	Units
U10M	Eastward (zonal) wind at 10 m above displacement height	m s^{-1}
V10M	Meridional (zonal) wind at 10 m above displacement height	m s^{-1}
T10M	Temperature interpolated to 10 m above the displacement height	K
QV10M	Specific humidity interpolated to 10 m above the displacement height	kg kg^{-1}
T2M	Temperature interpolated to 2 m above the displacement height	K
QV2M	Specific humidity interpolated to 2 m above the displacement height	kg kg^{-1}

- **tavg2d_met_x** (1 file per time, 8 files per day: 01:30, 04:30, 07:30, 10:30, 13:30, 16:30, 19:30, 22:30 GMT)

  Description: Time averaged 2D miscellaneous fields, single-level/vertical average
  Dimensions:
  longitude: 540
  latitude: 361
  Number of 2D variables: 21
  Size: 17 MB (8.5MB)
  Size/day: 136 MB (68 MB)

Variable Name	Description	Units
PS	Surface pressure	Pa
SLP	Sea-level pressure	Pa
PHIS	Surface geopoptential	m^2s^{-2}
CAPE	Convective Available Potential Energy	
CLDHGH	High-level (above 400 hPa) cloud fraction	fraction
CLDLOW	Low-level (1000-700 hPa) cloud fraction	fraction
CLDMID	Mid-level (700-400 hPa) cloud fraction	fraction
CLDTOT	Total cloud fraction	fraction
PBLH	Planetary boundary layer height	m
DISPH	Displacement height	m
PRECANV	Surface precipitation flux from anvils	kg m^{-2} s^{-1}
PRECCON	Surface precipitation flux from convection	kg m^{-2} s^{-1}
PRECLSC	Surface precipitation flux from large-scale	kg m^{-2} s^{-1}
PRECSNO	Surface snowfall flux	kg m^{-2} s^{-1}
PRECTOT	Total surface precipitation flux	kg m^{-2} s^{-1}
TO3	Total Column Ozone	Dobson
TPW	Total precipitable water	kg m^{-2}
TROPP	Tropopause pressure	Pa
TROPQ	Tropopause specific humidity	kg kg^{-1}
TROPT	Tropopause temperature	K
TTO3	Tropospheric Total Ozone Column	Dobson

- **tavg3d_chm_p** (1 file per time, 8 files per day: 01:30, 04:30, 07:30, 10:30, 13:30, 16:30, 19:30, 22:30 GMT)

Description: Time averaged 3D chemical state on pressure coordinates
Dimensions:
longitude: 540
latitude: 361
vertical layers (lcv): 26
Number of 2D variables: 2
Number of 3D variables: 3
Size: 62 MB (31MB)
Size/day: 496 MB (248 MB)

Variable Name	Description	Units
LWI	Land-Water-Ice mask	none
PS	Surface pressure (2D)	Pa
CO	Carbon monoxide volume mixing ratio	kg kg^{-1}
CO_2	Carbon dioxide volume mixing ratio	kg kg^{-1}
O_3	Ozone mass mixing ratio	kg kg^{-1}

- **tavg2d_chm_x** (1 file per time, 8 files per day: 01:30, 04:30, 07:30, 10:30, 13:30, 16:30, 19:30, 22:30 GMT)

Description: Time averaged 2D chemical state, single level/vertical average
Dimensions:
longitude: 540
latitude: 361
vertical layers (lcv): 26
Number of 2D variables: 6
Size: 5 MB (2.5 MB)
Size/day: 40 MB (20 MB)

Variable Name	Description	Units
SCO	Surface Carbon Monoxide	kg m^{-2}
SCO2	Surface Carbon Dioxide	kg m^{-2}
SO3	Surface ozone	kg/kg
TO3	Total Column Ozone	Dobson
TCO	Carbon Monoxide Column Burden	kg m^{-2}
TCO2	Carbon Dioxide Column Burden	kg m^{-2}

- **tavg3d_aer_p** (1 file per time, 8 files per day: 01:30, 04:30, 07:30, 10:30, 13:30, 16:30, 19:30, 22:30 GMT)

Description: Time averaged 3D aerosol state on pressure coordinates
Dimensions:
longitude: 540
latitude: 361
vertical layers (lcv): 26
Number of 2D variables: 2
Number of 3D variables: 6
Size: 122 MB (61 MB)
Size/day: 976 MB (488 MB)

Variable Name	Description	Units
LWI	Land-Water-Ice mask	none
PS	Surface pressure (2D)	Pa
DU	Dust Mass Mixing Ratio	kg/kg
SS	Seasalt Mass Mixing Ratio	kg/kg
BC	Black Carbon Mass Mixing Ratio	kg/kg
OC	Organic Carbon Mass Mixing Ratio	kg/kg
SO2	SO_2 Aerosol Mass Mixing Ratio	kg/kg
SO4	SO_4 Aerosol Mass Mixing Ratio	kg/kg

- **tavg2d_aer_x** (1 file per time, 8 files per day: 01:30, 04:30, 07:30, 10:30, 13:30, 16:30, 19:30, 22:30 GMT)

  Description: Time averaged 2D miscellaneous aerosol fields, single level/vertical average
  Dimensions:
  longitude: 540
  latitude: 361
  vertical layers (lcv): 102
  Number of 2D variables:
  Size: 82 MB (41 MB)
  Size/day: 656 MB (328 MB)

Variable Name	Description	Units
CLDTOT	Total cloud cover	fraction
GWETTOP	Top soil layer wetness	fraction
H500	500 hPa Geopotential height	m
LWI	Surface type flag	flag
PBLH	Planetary boundary layer height	m
PREACC	Total precipitation rate	mm/day
SLP	Sea level pressure	Pa
TQ	Total precipitable water	kg/m^2
DUEM001	Dust Emission Bin 1	$kg/m^2/s$
DUEM002	Dust Emission Bin 2	$kg/m^2/s$
DUEM003	Dust Emission Bin 3	$kg/m^2/s$
DUEM004	Dust Emission Bin 4	$kg/m^2/s$
DUEM005	Dust Emission Bin 5	$kg/m^2/s$
DUSD001	Dust Sedimentation Bin 1	$kg/m^2/s$
DUSD002	Dust Sedimentation Bin 2	$kg/m^2/s$
DUSD003	Dust Sedimentation Bin 3	$kg/m^2/s$
DUSD004	Dust Sedimentation Bin 4	$kg/m^2/s$
DUSD005	Dust Sedimentation Bin 5	$kg/m^2/s$
DUDP001	Dust Dry Deposition Bin 1	$kg/m^2/s$
DUDP002	Dust Dry Deposition Bin 2	$kg/m^2/s$
DUDP003	Dust Dry Deposition Bin 3	$kg/m^2/s$
DUDP004	Dust Dry Deposition Bin 4	$kg/m^2/s$
DUDP005	Dust Dry Deposition Bin 5	$kg/m^2/s$
DUWT001	Dust Wet Deposition Bin 1	$kg/m^2/s$
DUWT002	Dust Wet Deposition Bin 2	$kg/m^2/s$

Variable Name	Description	Units
DUWT003	Dust Wet Deposition Bin 3	$kg/m^2/s$
DUWT004	Dust Wet Deposition Bin 4	$kg/m^2/s$
DUWT005	Dust Wet Deposition Bin 5	$kg/m^2/s$
DUSMASS	Dust Surface Mass Concentration	kg/m^3
DUCMASS	Dust Column Mass Density	kg/m^2
DUEXTTAU	Dust Extinction AOT 550 nm	unitless
DUSCATAU	Dust Scattering AOT 550 nm	unitless
DUAERIDX	Dust TOMS UV Aerosol Index	unitless
SSEM001	Seasalt Emission Bin 1	$kg/m^2/s$
SSEM002	Seasalt Emission Bin 2	$kg/m^2/s$
SSEM003	Seasalt Emission Bin 3	$kg/m^2/s$
SSEM004	Seasalt Emission Bin 4	$kg/m^2/s$
SSEM005	Seasalt Emission Bin 5	$kg/m^2/s$
SSSD001	Seasalt Sedimentation Bin 1	$kg/m^2/s$
SSSD002	Seasalt Sedimentation Bin 2	$kg/m^2/s$
SSSD003	Seasalt Sedimentation Bin 3	$kg/m^2/s$
SSSD004	Seasalt Sedimentation Bin 4	$kg/m^2/s$
SSSD005	Seasalt Sedimentation Bin 5	$kg/m^2/s$
SSDP001	Seasalt Dry Deposition Bin 1	$kg/m^2/s$
SSDP002	Seasalt Dry Deposition Bin 2	$kg/m^2/s$
SSDP003	Seasalt Dry Deposition Bin 3	$kg/m^2/s$
SSDP004	Seasalt Dry Deposition Bin 4	$kg/m^2/s$
SSDP005	Seasalt Dry Deposition Bin 5	$kg/m^2/s$
SSWT001	Seasalt Wet Deposition Bin 1	$kg/m^2/s$
SSWT002	Seasalt Wet Deposition Bin 2	$kg/m^2/s$
SSWT003	Seasalt Wet Deposition Bin 3	$kg/m^2/s$
SSWT004	Seasalt Wet Deposition Bin 4	$kg/m^2/s$
SSWT005	Seasalt Wet Deposition Bin 5	$kg/m^2/s$
SSSMASS	Seasalt Surface Mass Concentration	kg/m^3
SSCMASS	Seasalt Column Mass Density	kg/m^2
SSEXTTAU	Seasalt Extinction AOT 550 nm	unitless
SSSCATAU	Seasalt Scattering AOT 550 nm	unitless
BCEM001	Black Carbon Emission Bin 1	$kg/m^2/s$
BCEM002	Black Carbon Emission Bin 2	$kg/m^2/s$
BCDP001	Black Carbon Deposition Bin 1	$kg/m^2/s$
BCDP002	Black Carbon Deposition Bin 2	$kg/m^2/s$
BCWT001	Black Carbon Wet Deposition Bin 1	$kg/m^2/s$
BCWT002	Black Carbon Wet Deposition Bin 2	$kg/m^2/s$
BCSMASS	Black Carbon Surface Mass Concentration	kg/m^3
BCCMASS	Black Carbon Column Mass Density	kg/m^2
BC	Black Carbon Extinction AOT 550 nm	unitless
BCSCATAU	Black Carbon Scattering AOT 550 nm	unitless
OCEM001	Organic Carbon Emission Bin 1	$kg/m^2/s$
OCEM002	Organic Carbon Emission Bin 2	$kg/m^2/s$
OCDP001	Organic Carbon Deposition Bin 1	$kg/m^2/s$
OCDP002	Organic Carbon Deposition Bin 2	$kg/m^2/s$
OCWT001	Organic Carbon Wet Deposition Bin 1	$kg/m^2/s$
OCWT002	Organic Carbon Wet Deposition Bin 2	$kg/m^2/s$

Variable Name	Description	Units
OCSMASS	Organic Carbon Surface Mass Concentration	kg/m^3
OCCMASS	Organic Carbon Column Mass Density	kg/m^2
OCEXTTAU	Organic Carbon Extinction AOT 550 nm	unitless
OCSCATAU	Organic Carbon Scattering AOT 550 nm	unitless
SUEM001	Sulfate Emission Bin 1	$kg/m^2/s$
SUEM002	Sulfate Emission Bin 2	$kg/m^2/s$
SUEM003	Sulfate Emission Bin 3	$kg/m^2/s$
SUEM004	Sulfate Emission Bin 4	$kg/m^2/s$
SUDP001	Sulfate Deposition Bin 1	$kg/m^2/s$
SUDP002	Sulfate Deposition Bin 2	$kg/m^2/s$
SUDP003	Sulfate Deposition Bin 3	$kg/m^2/s$
SUDP004	Sulfate Deposition Bin 4	$kg/m^2/s$
SUWT001	Sulfate Wet Deposition Bin 1	$kg/m^2/s$
SUWT002	Sulfate Wet Deposition Bin 2	$kg/m^2/s$
SUWT003	Sulfate Wet Deposition Bin 3	$kg/m^2/s$
SUWT004	Sulfate Wet Deposition Bin 4	$kg/m^2/s$
SO2SMASS	SO2 Surface Mass Concentration	kg/m^3
SO2CMASS	SO2 Column Mass Density	kg/m^2
SO4SMASS	SO4 Surface Mass Concentration	kg/m^3
SO4CMASS	SO4 Column Mass Density	kg/m^2
DMSSMASS	SO2 Surface Mass Concentration	kg/m^3
DMSCMASS	SO2 Column Mass Density	kg/m^2
SUPSO2	SO2 Production from DMS Oxidation column integrated	$kg/m^2/s$
SUPSO4G	SO4 Production from gas-phase SO2 Oxidation column integrated	$kg/m^2/s$
SUPSO4AQ	SO4 Production from aqueous SO2 Oxidation (column)	$kg/m^2/s$
SUPMSA	MSA Production from DMS Oxidation column integrated	$kg/m^2/s$
SUPSO4WT	SO_4 Production from aqueous SO2 Oxidation (wet dep) column integrated	$kg/m^2/s$
SUEXTAU	SO_4 Extinction AOT 550 nm	unitless
SUSCATAU	SO_4 Scattering AOT 550 nm	unitless

- **tavg2d_hwl_x** (1 file per time, 24 files per day: 00, 01, 02, …, 23 GMT)
  Description: Instantaneous 2D fields for Hyperwall, single level/vertical average
  Dimensions:
  longitude: 540
  latitude: 361
  Number of 2D variables: 14
  Size: 11 MB (5.5 MB)
  Size/day: 264 MB (132 MB)

Variable Name	Description	Units
H500	500 hPa Geopotential height	m
SLP	Sea level pressure	Pa

Variable Name	Description	Units
PRECTOT	Total surface precipitation flux	kg m^{-2} s^{-1}
DU	Dust Extinction AOT 550 nm	none
SS	Seasalt Extinction AOT 550 nm	none
BC	Black Carbon Extinction AOT 550 nm	
OC	Organic Carbon Extinction AOT 550 nm	
SU	SO4 Extinction AOT 550 nm	none
SCO	Surface Carbon Monoxide	kg m^{-2}
SCO2	Surface Carbon Dioxide	kg m^{-2}
SO3	Surface ozone	kg/kg
TO3	Total Column Ozone	Dobson
TCO	Carbon Monoxide Column Burden	kg/m^2
TCO2	Carbon Dioxide Column Burden	kg/m^2

6.4 Forecast Files – ¼ x 1/3 Degree Resolution: Once-daily at 12Z

- **inst3d_met_p** (1 time per file, 8 files per day: 00, 03, 06, 09, 12, 15, 18, 21 GMT)
  Description: 3D meteorological state, instantaneous on pressure coordinates
  Dimensions:
  longitude: 1080
  latitude: 721
  vertical pressure levels: 26
  Number of 3D variables: 8
  Number of 2D variables: 10
  Size: 824 MB (412 MB)
  Size/day: 6592 MB (3296 MB)

Variable Name	Description	Units
	Same variables as **inst3d_met_p** in section 6.3	

- **tavg2d_met_x** (1 file per time, 8 files per day: 01:30, 04:30, 07:30, 10:30, 13:30, 16:30, 19:30, 22:30 GMT)
  Description: Time averaged 2D miscellaneous fields, single-level/vertical average
  Dimensions:
  longitude: 1080
  latitude: 721
  Number of 2D variables: 21
  Size: 63 MB (31.5 MB)
  Size/day: 504 MB (252 MB)

Variable Name	Description	Units
	Same variables as **tavg2d_met_x** in section 6.3	

6.5 Analysis/Assimilation Files – ½ by 1/3 Degree Resolution:

The GMAO will continue producing its standard data products as described in the *File Specification for GEOS-5 DAS Gridded Output.* All the quantities listed in that document will be made available in the OpenDAP server http://opendap.gsfc.nasa.gov:9090/dods/GEOS-5/TC4. However, the individual datasets will not contain the additional HDF-EOS metadata described in the GEOS-5 FileSpec document.

- **inst3d_chm_v** (1 file per time, 4 files per day: 00, 06, 12 and 18 GMT)

  Description: Instantaneous 3D chemical state on LCV coordinates
  Dimensions:
    longitude: 540
    latitude: 361
    levels : 72
  Number of 2D variables: 2
  Number of 3D variables: 4
  Size: 226 MB (113 MB)
  Size/day: 1808 MB (904 MB)

Variable Name	Description	Units
LWI	Land-Water-Ice mask	none
PS	Surface pressure (2D)	Pa
DELP	Pressure difference between layer edges	Pa
CO	Carbon monoxide volume mixing ratio	mol/mol
CO_2	Carbon dioxide volume mixing ratio	mol/mol
O_3	Ozone mass mixing ratio	$kg\ kg^{-1}$

- **tavg3d_chm_p** (1 file per time, 8 files per day: 01:30, 04:30, 07:30, 10:30, 13:30, 16:30, 19:30, 22:30 GMT)

  Description: Time averaged 3D chemical state on pressure coordinates
  Dimensions:
    longitude: 540
    latitude: 361
    levels: 26
  Number of 2D variables: 2
  Number of 3D variables: 3
  Size: 62 MB (31 MB)
  Size/day: 496 MB (248 MB)

Variable Name	Description	Units
	Same variables as **tavg3d_chm_p** in section 6.3	

- **tavg2d_chm_x** (1 file per time, 8 files per day: 01:30, 04:30, 07:30, 10:30, 13:30, 16:30, 19:30, 22:30 GMT)

  Description: Time averaged 2D chemical state, single level/vertical average
  Dimensions:
    longitude: 540
    latitude: 361

Number of 2D variables: 6
Size: 5 MB (2.5 MB)
Size/day: 40 MB (20 MB)

Variable Name	Description	Units
	Same variables as **tavg2d_chm_x** in section 6.3	

- **inst3d_aer_v** (1 file per time, 4 files per day: 00, 06, 12 and 18 GMT)

  Description: Instantaneous 3D aerosol state on LCV coordinates
  Dimensions:
    longitude: 540
    latitude: 361
  Number of 2D variables: 3
  Number of 3D variables: 19
  Size: 1066 MB (533 MB)
  Size/day: 8528 MB (4264 MB)

Variable Name	Description	Units
LWI	Land-Water-Ice mask	None
PS	Surface pressure (2D)	Pa
DELP	Pressure difference between layer edges	Pa
RH	Relative humidity	percent
DU001	Dust mass mixing ratio – Bin 001	kg kg^{-1}
DU002	Dust mass mixing ratio – Bin 002	kg kg^{-1}
DU003	Dust mass mixing ratio – Bin 003	kg kg^{-1}
DU004	Dust mass mixing ratio – Bin 004	kg kg^{-1}
DU005	Dust mass mixing ratio – Bin 005	kg kg^{-1}
SS001	Sea salt mass mixing ratio – Bin 001	kg kg^{-1}
SS002	Sea salt mass mixing ratio – Bin 002	kg kg^{-1}
SS003	Sea salt mass mixing ratio – Bin 003	kg kg^{-1}
SS004	Sea salt mass mixing ratio – Bin 004	kg kg^{-1}
SS005	Sea salt mass mixing ratio – Bin 005	kg kg^{-1}
DMS	Dimethylsulphide	kg kg^{-1}
SO2	Sulphur dioxide	kg kg^{-1}
SO4	Sulphate aerosol	kg kg^{-1}
MSA	Methanesulphonic acid	kg kg^{-1}
BCphobic	Hydrophobic Black Carbon	kg kg^{-1}
BCphilic	Hydrophilic Black Carbon	kg kg^{-1}
OCphobic	Hydrophobic Organic Carbon (Particulate Matter)	kg kg^{-1}
OCphilic	Hydrophilic Organic Carbon (Particulate Matter)	kg kg^{-1}

- **tavg3d_aer_p** (1 file per time, 8 files per day: 01:30, 04:30, 07:30, 10:30, 13:30, 16:30, 19:30, 22:30 GMT)

  Description: Time averaged 3D aerosol concentration on pressure coordinates
  Dimensions:
    longitude: 540
    latitude: 361
  Number of 2D variables: 2
  Number of 3D variables: 6
  Size: 122 MB (61 MB)

Size/day: 976 MB (488 MB)

Variable Name	Description	Units
	Same variables as **tavg3d_aer_p** in section 6.3	

- **tavg2d_aer_x** (1 file per time, 8 files per day: 01:30, 04:30, 07:30, 10:30, 13:30, 16:30, 19:30, 22:30 GMT)

  Description: Time average 2D aerosol diagnostics
  Dimensions:
  longitude: 540
  latitude: 361
  Number of 2D variables: 102
  Size: 82 MB (41 MB)
  Size/day: 656 MB (328 MB)

Variable Name	Description	Units
	Same variables as **tavg2d_aer_x** in section 6.3	

- **tavg2d_hwl_x** (1 file per time, 24 files per day: 00, 01, 02, …, 23 GMT)

  Description: Instantaneous 2D fields for Hyperwall, single level/vertical average
  Dimensions:
  longitude: 540
  latitude: 361
  Number of 2D variables: 14
  Size: 11 MB (5.5 MB)
  Size/day: 88 MB (44 MB)

Variable Name	Description	Units
	Same variables as **tavg2d_hwl_x** in section 6.3	

Appendix A. Types of Assimilation Configurations

Operational Assimilation: Atmospheric observations from satellites, balloons, aircraft, ships, and other sources are grouped into six-hour data windows and processed by the atmospheric analysis four times each day. The operational analysis will run approximately 12 hours after the 4 analysis times (0Z, 6Z, 12Z, 18Z). It will run using whatever conventional and satellite observations are available at the data cut-off time. Products produced from this and any other *assimilation* are a combination of output from the statistical analysis system and a short GCM forecast.

Forecast/Simulation: This is a GCM forecast, with no insertion of atmospheric data via the analysis. The only outside data that enters the system are the boundary conditions, i.e., sea surface temperature and sea-ice concentration. Five-day forecasts are typically generated to support NASA field campaigns and to assess assimilation and forecast skill. Multi-year simulations are produced to investigate the climatology of the GCM. GMAO forecast products are not distributed to ECS and file formats are not discussed in this document.

Reprocessing: The GMAO may reprocess specified time periods since EOS-Terra launch using a recent version of the GEOS DAS software to support instrument team reprocessing requirements. It is expected that new ECS ESDTs will be generated for each reprocessing run.

Reanalysis: The GMAO will occasionally run reanalysis experiments. Reanalysis is the same as reprocessing except the time period is often much longer and not necessarily part of the EOS period. Reanalysis experiments are often run using baseline versions of the GEOS DAS system to support a wide variety of research activities internal and external to the GMAO. Unique ESDTs will be generated for any reanalysis data distributed through GES DAAC.

Appendix E: Detailed Description of Output Variables

E.1: 3D Variables

CLOUD: The horizontal fractional cloud cover for each layer. In the vertical, clouds are assumed to fill the layer. This fraction is the combination of the model's predicted large-scale and convective fractions that is used for radiative purposes. See **CLDTOT** for a description of how these fractions are overlapped in the radiation calculations.

CMFMC: The total vertical convective mass flux through levels between model layers (edges), in kg m^{-2} s^{-1}. This is produced by the convection parameterization (RAS) and it includes the mass flux due to all cloud types crossing the level.

DELP: Pressure thickness of model layers, in Pa. See **PLE**. The layer mass is **DELP / 9.81** kg m^{-2}.

DQRCON, DQRLSC: The layer production rate of precipitating condensate from convective and large-scale processes per unit horizontal area, in kg m^{-2} s^{-1} Includes both liquid and frozen precipitating condensate, but not the production cloud condensates.

DQVDTMST, DQLDTMST, DQIDTMST: Tendency of vapor, liquid and ice water due to moist processes, in kg kg^{-1} s^{-1}. This includes the effects of the convection parameterization (RAS) and all other effects from the cloud microphysics and large scale and anvil precipitation schemes.

DQVDTDYN: Tendency of water vapor due to resolved dynamics, in kg kg^{-1} s^{-1}.

DQVDTTRB: Tendency of water vapor due to turbulence, including surface evaporation, in kg kg^{-1} s^{-1}.

DTDTDYN: Temperature tendency due to dynamics, including the spurious frictional dissipation of kinetic energy by numerical processes.

DTDTFRI: Temperature tendency due to the frictional dissipation of kinetic energy by turbulence, including surface friction, in K s^{-1}. It does not include dissipation from gravity wave drag or the implicit dissipation in the model's dynamics.

DTDTGWD: Temperature tendency due to the frictional dissipation of kinetic energy by gravity wave drag, in K s^{-1}.

DTDTLWR, DTDTLWRCLR: Temperature tendency due to terrestrial (longwave) radiation for all-sky and clear-sky conditions, in K s^{-1}.

DTDTMST: Temperature tendency due to terrestrial (longwave) radiation, in K s^{-1}.

DTDTSWR, DTDTSWRCLR: Temperature tendency due to solar (shortwave) radiation for all-sky and clear-sky conditions, in K s^{-1}.

DTDTTOT: The total diabatic temperature tendency for the model layers, in K s^{-1} . It is the same as the sum **DTDTFRI+DTDTGWD+DTDTLWR+DTDTSWR+DTDTMST+DTDTTRB,** and in the lon-term mean should balance **DTDTDYN**.

DTDTTRB: Temperature tendency due to turbulence, including surface sensible heat flux, but not including the heating due to frictional dissipation (see **DTDTFRI**), in K s^{-1}. Above the surface it includes the diffusive effects due to the Louis and Lock turbulence schemes (see **KH**).

DTRAIN: Mass flux detrained at cloud top from each convective cloud type in RAS, the model's convection parameterization, in kg m^{-2} s^{-1}.

DUDTDYN, DVDTDYN: Eastward (zonal) and northward (meridional) wind tendency due to dynamics, in m s^{-2}.

DUDTGWD, DVDTGWD: Eastward (zonal) and northward (meridional) wind tendencies due to gravity wave drag, in m s^{-2}.

DUDTMST, DVDTMST: Eastward (zonal) and northward (meridional) wind tendencies due to moist processes, in m s^{-2}. Currently this represents the "cumulus friction" effect of mixing momentum in a conservative way, using the convective mass fluxes from RAS.

DUDTTRB, DVDTTRB: Eastward (zonal) and northward (meridional) wind tendencies due to turbulent processes, in m s^{-2}. This includes surface friction. Above the surface, it includes the diffusive effects due to the Louis and Lock turbulence schemes (see **KM**).

HGHT: Geopotential height at the layer centers, in m. It is simply the average of **HGHTE** at the layer's bounding edges.

HGHTE: Geopotential height at the layer edges, in m. At the surface (LM+1) it is set to **PHIS**/g**.** Above the surface $\frac{1}{g}\left(\ \mathbf{PHIS} + c_P \sum_{l=L}^{LM} \theta_v \Delta P\ \right)$, where ΔP is the difference in $\left(\frac{p}{p_o}\right)^{\kappa}$ at the lower and upper edges of layer l, and θ_v is the virtual potential temperature,

KH, KM : Turbulent diffusivity for heat and other scalars and for momentum (**U** and **V**), in m^2 s^{-1}. This is defined at the layer edges, beginning at the top, where it is zero. At the surface (LM+1) it is set ….. It includes the diffusive effects due to the Louis and Lock turbulence schemes.

MFXC, MFYC: The eastward and northward layer mass fluxes on the C-Grid, in Pa m^2 s^{-1}. **MF[X,Y]C** = $[\mathbf{U},\mathbf{V}]\mathrm{DELP}[a\Delta\varphi, a\cos(\varphi)\Delta\lambda]$, where **U** and **V** are the C-grid velocity components, a is the earth's radius, and $[a\Delta\varphi, a\cos(\varphi)\Delta\lambda] \equiv [\Delta y, \Delta x]$ are the meridional and zonal grid spacings at the appropriate C-grid locations, in meters.

MFZ: The vertical component of the large-scale mass flux at the lcv edges, in kg m^{-2} s^{-1}. Together with **MFXC, MFYC,** and **PS,** these satisfy the continuity equation

$$\frac{\partial}{\partial t}\mathrm{PS} = -\frac{1}{\Delta y \Delta x}(\delta_x\ \mathrm{MFXC} + \delta_y\ \mathrm{MFYC}) - \mathrm{g}\,\delta_z\ \mathrm{MFZ}$$

OMEGA: The kinematic vertical pressure velocity estimated by the Finite-Volume dynamics. It is defined for the layers, not the edges. For layer l, it is discretized vertically as

$$\omega_l = \left(\overline{\frac{\partial p}{\partial t}} + \overline{\dot{\eta}\frac{\partial p}{\partial \eta}}\right)_l + (V \bullet \nabla \overline{p})_l,$$

where the pressure is defined at the layer edges and the overbar indicates the average of the layer's upper and lower edges.

PL: The layer pressure defined as the average of the upper and lower edge pressures, **PLE,** in Pa (see **DELP**).

PLE: The time-averaged pressure at the upper edge of a layer**. PLE** = **PS** + $\sum_{l=L}^{LM}$ **DELP** $_l$. This is the preferred way of obtaining edge pressures in lcv-coordinates, rather than relying on the model's hybrid-sigma coordinate system (i.e., the **AK**s and **BK**s), which may change in future releases.

PV: A modified Ertel's potential vorticity, approximated as $g(\zeta + f)\frac{\partial \ln(\theta_v)}{\partial p}$, in m^2 kg^{-1} sec^{-1}.

Here ζ is the vertical component of relative vorticity, f is the Coriolis parameter, and θ_v is the virtual potential temperature. Note the definition in terms of entropy instead of potential temperature and the neglect of the part associated with the horizontal components of vorticity.

TAUCLI, TAUCLW: Each layer's total cloud optical thickness in the visible (0.40 to 0.69 micron band), for ice clouds and liquid water clouds, respectively.

E.2: 2D Variables

ALBEDO: The time-averaged surface albedo defined as the ratio of the time-averaged incident and reflected fluxes and should satisfy **ALBEDO = SWGDWN/(SWGDWN-SWGNET).** At night points, this is set to **_FillValue**.

ALBVISDF, ALBVISDR, ALBNIRDF, ALBNIRDR: The direct (beam) and diffuse albedos for the "visible" (the GCM uses the same albedos for the UV and the PAR spectral regions—0.175 to 0.69 microns) and the "near-infrared" (0.69 to 3.85 microns). These are simply time-averaged surface properties, but are defined only where there was daylight at the point during the averaging interval. They do not correspond to the ratios of time-averaged incident and reflected fluxes.

BSTAR: The buoyancy scale of the surface layer in m s^{-2}. It is defined as $\frac{g}{\rho_a u^*}\frac{F_{s_v}}{c_P T_a}$, where ρ_a is the near-surface air density (**RHOA**) and T_a the near-surface air temperature, u^* is the friction velocity (**USTAR**), and F_{s_v} is the surface flux of virtual dry static energy in W m^{-2}, F_{s_v} = (**HFLUX** + $(1-\varepsilon)$ **EFLUX**).

CLDHGH, CLDMID, CLDLOW, CLDTOT: High, middle, low, and total cloudiness. The high, middle, low-level values correspond to the three superlayers used in the GEOS-5 solar and terrestrial radiation parameterizations. Clouds within these superlayers are assumed to be maximally overlapped. High clouds are those occurring above roughly 400 hPa and low clouds are those occurring below 700 hPa, although the groupings are done ion the model's terrain following coordinate and so the bounding pressures will differ significantly from these values over high topography. The model assumes that the overlapped between the superlayers is random, and the total cloudiness uses this assumption. The total cloudiness is computed each time the radiation is called, and so its time mean cannot be exactly constructed from the time-mean cloudiness in the three super layers.

DISPH: Surface displacement height in meters. See the description of the neutral drag coefficient.

DTG: Change in surface temperature during the averaging interval in deg K. This refers to the area-mean surface temperature under each atmospheric column, and so, it may contain contributions from land-, water-, and ice-covered parts of the grid box.

EFLUX: The upward turbulent flux of latent heat flux at the surface, in W m^{-2}. This includes the latent heat relative to liquid of all turbulent moisture fluxes through the surface (see **EVAP**).

EMIS: The surface emissivity. This is a really averaged over all surface tiles and is constant in time.

EVAP: Evaporation in kg m^{-2} s^{-1}. Actually the total turbulent flux of water vapor at the surface, including fluxes from transpiration, sublimation, and surface condensation. The turbulent flux of could condensate (fog) is assumed to be zero. .

FRLAKE, FRLAND, FRLANDICE, FROCEAN: GEOS-5 uses these four primary surface types and these are their fractions under each atmospheric column.

GRN: The "greenness" or fraction transpiring leaves averaged over the land areas of a grid box. If there are several vegetation tiles within the land part of a grid box, the average is **LAI** weighted. **GRN** is set to **_FillValue** where **FRLAND** = 0.

GWETROOT, GWETTOP: The degree of saturation or "wetness" in the root-zone (top meter of soil) and top soil layer (top 2 cm). These are defined as the ratio of the volumetric soil moisture to the porosity. These quantities are set to **_FillValue** where **FRLAND** = 0. Elsewhere they are time-mean and area-mean values of the ratio over the land part of the grid box.

HFLUX: The upward turbulent sensible heat flux at the surface, in W m^{-2}.

LAI: The a real average of the leaf-area index over all land parts of a grid box. **LAI** is set to **_FillValue** where **FRLAND** = 0.

LWGDWN, LWGDWNCLR: The all-sky and cloud-free fluxes of downwelling terrestrial (longwave) radiation at the surface in W m^{-2}.

LWGNET: The net downward flux of terrestrial (longwave) radiation at the surface in W m^{-2}. This is identical to **LWGDWN- LWGUP.**

LWGUP: The all-sky upwelling terrestrial (longwave) radiation at the surface, in W m^{-2}. This includes both the surface emission and the reflection..

LWI: A Land-Water-Ice mask provided for backward compatibility with the GEOS-4 product. It is 1 over continental areas, 0 over open ocean, and 2 over sea-ice covered ocean. Since in GEOS-5 a grid box can be a combination of these, continental areas are arbitrarily defined as those where **FRLAND+FRLANDICE>=0.5.** The remaining grid boxes are designated as sea-ice if the ice cover exceeds 50%; otherwise they are open (ice-free) ocean.

LWTUP, LWTUPCLR: Outgoing longwave (terrestrial) radiation at the top of the model's atmosphere (currently 0.01 hPa) for all-sky and clear-sky conditions, in W m^{-2}.

PARDF, PARDR: Incident flux of of diffuse and direct PAR at the surface, in W m^{-2}. PAR is defied as the solar radiation between 0.4 and 0.69 microns.

PBLH: Height above the surface of the planetary boundary layer in meters. This is obtained diagnostically at every time step from the heat diffusivity in the model layers. It is defined as the height of the lowest layer in which the diffusivity falls below 2 $m^2 s^{-1}$. Where no layer is above this value, the boundary layer height is set to the height of the surface layer.

PHIS: The surface geopotential, gh_s, in m^{-2} s^{-2}. Here h_s is the height of the surface above sea level, and $g = 9.81$ m s^{-2}.

PRECANV, PRECLSC, PRECCON: the large-scale precipitation from anvils, the non-anvil large-scale precipitation, and the convective precipitation, in kg m^{-2} s^{-1}. These include both rainfall and snowfall.

PRECTOT: The total precipitation (**PRECANV+PRECLSC+PRECCON**) in kg m^{-2} s^{-1}.

PRECSNO: The "snowfall" includes all frozen precipitation, in kg m^{-2} s^{-1}.

PS: The surface pressure in Pa. The height at this pressure can be obtained from the surface geopotential **PHIS.** The total atmospheric mass is $\frac{1}{g}\mathbf{PS}$ kg m^{-2}.

QV10M, QV2M: The specific humidity at 10 m and 2m above the displacement height (**DISPH**) in the surface layer, in kg kg^{-1}.

RHOA: Surface air density in the lowest model layer, in kg m^{-3}. This is the density used in bulk formulas.

SLP: The surface pressure reduced to sea level, in Pa. Over topography the reduction is done by assuming a lapse rate of 6.5 K km^{-1} from a free atmospheric temperature, which is currently taken as the lowest model layer above 150 hPa above the surface.

SNOMAS: The mass of snow in per unit of land area in meters of liquid-water-equivalent depth (i.e., 10^3 kg m^{-2}). In grid boxes with no land (**FRLAND+FRLANDICE=0**) it is set to **_FillValue.** Where **FRLANDICE>0.9** it is arbitrarily set to 4 meters. Over other land areas it represents an average over the non-glaciated part.

SNODP: The geometric snow depth in meters. This accounts for packing and aging of the snow.

SWGDWN, SWGDWNCLR: Incident solar radiation (0.175 to 3.85 microns) at the surface for all-sky and clear-sky conditions, in W m^{-2}. Since we do a single atmospheric transfer calculation in a grid box, we assume the incident diffuse radiation is the same for all land tiles within the box.

SWGNET, SWGNETCLR: Net downward flux of solar radiation at the surface averaged over all land tiles for all-sky and clear-sky conditions, in W m^{-2}.

SWTUP, SWTUPCLR: The outgoing (reflected) flux of solar radiation at the top of the model's atmosphere (currently 0.01 hPa) for all-sky and clear-sky conditions, in W m^{-2}.

SWTDWN: Incident flux of solar radiation at the top of the atmosphere, in W m^{-2}.

T10M, T2M: The air temperature at 10 m and 2m above the displacement height (**DISPH**) in the surface layer, in K.

TAUGWX, TAUGWY: The eastward (zonal) and northward (meridional) components of the atmospheric stress on the surface due to atmospheric gravity wave drag, in N m^{-2}.

TAUHGH, TAUMID, TAULOW, TAUTOT: Total cloud optical thickness in the 0.40 to 0.69 micron band for the high, middle, and low cloud regions (see **CLDHGH)** and for the entire column.

TAUX, TAUY: The eastward (zonal) and northward (meridional) components of the atmospheric frictional stress on the surface, in N m^{-2}.

TO3 : The vertically integrated ozone, in Dobson units.

TPW, TQV: The vertically integrated water vapor in the column, in kg m^{-2}.. These are synonyms.

TQL, TQI: The vertically integrated liquid and ice water in the column, in kg m^{-2}.

TQC: The vertically integrated combined liquid and ice water in the column, in kg m^{-2}.

TROPP: The tropopause pressure in Pa. The tropopause pressure is defined as the pressure where the function $\alpha T(p) - \log_{10} p$ reaches its first minimum above the surface. Here $\alpha = 0.03$ and p is in hPa. If no minimum is found between 550 hPa and 40 hPa, **TROPP** is set to **_FillValue.**

TROPQ: The tropopause specific humidity in kg kg^{-1}. The tropopause is defined as in **TROPP.**

TROPT: The tropopause temperature in K. The tropopause is defined as in **TROPP.**

TSKIN: The area weighted skin temperature of all surface tiles in a grid box, in K.

TTO3: The vertically integrated ozone in the troposphere, in Dobson units. The troposphere is defined as all levels below **TROPP. TTO3** and **TROPP** are computed at every time step and averaged separately.

U50M, U10M, U2M: The eastward wind component at 50m, 10 m, and 2m above the displacement height (**DISPH**) in the surface layer, in m s^{-1}.

USTAR: The surface friction velocity, $u^* = \sqrt{\frac{|\tau|}{\rho_a}}$, in m s^{-1}. This mean quantity is formed by doing the the areal average over the surface tiles in a grid box instantaneously to $|\tau|$, and the time averaging on u^* itself. It is thus not exactly what would be obtained from **TAUX, TAUY**, and **RHOA**.

V50M, V10M, V2M: The northward wind component at 50m, 10 m, and 2m above the displacement height (**DISPH**) in the surface layer, in m s^{-1}.

Z0H: The surface roughness for heat, in m.

Z0M: The dynamic surface roughness, in m.

REFERENCES

GMAO web site: http://gmao.gsfc.nasa.gov/

GMAO Operations page: http://gmao.gsfc.nasa.gov/operations/

CF Standard Description: http://www.cgd.ucar.edu/cms/eaton/cf-metadata/CF-current.html

CF Standard Names: http://www.cgd.ucar.edu/cms/eaton/cf-metadata/standard_name.xml

Dopplick, T., 1997: The Role of Metadata in EOSDIS. EOSDIS Technical Paper 160-TP-013-001.

Gross, C., 1997: B.0 Earth Science Data Model for the ECS Project. EOSDIS Technical Paper 420-TP-015-001.

NOAA, 1995: Conventions for the Standardization of NetCDF Files (COARDS). http://ferret.wrc.noaa.gov/noaa_coop/coop_cdf_profile.html

NCSA, 1999: The NCSA HDF Home Page. http://hdf.ncsa.uiuc.edu/

SZIP compression in HDF: http://hdf.ncsa.uiuc.edu/doc_resource/SZIP/

NASA, 1999: HDF-EOS Standards. http://hdfeos.gsfc.nasa.gov/

deWitt, Shaun, 1996: Writing HDF-EOS Grid Products for Optimum Subsetting Services. ECS Technical Paper 170-TP-007-001.